3/27/01

UPPER RIO GRANDE WATER OPERATIONS MODEL

Forecast Model Documentation

CONTENTS

Introduction

During April 1998, the Upper Rio Grande Water Operations Model (URGWOM) technical team concluded that RiverWare© software, developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES), within the University of Colorado at Boulder, was the best choice of software to develop a model capable of simulating the complex river and reservoir system that comprise the Upper Rio Grande Basin.

Since April 1998, the URGWOM technical team has worked to develop four inter-related modules and an associated database to be used to model the upper basin. These four URGWOM modules have become known as the Water Operations Model, the Accounting Model, the Planning Model and the Forecast Model.

- The Water Operations Model will be used to set reservoir releases using "rules" of the policies and laws governing the releases from reservoirs and provide information throughout the river system, including San Juan-Chama (SJ) contractor water and Rio Grande (RG) water movements and storages.

- The Accounting Model is replacing the FORTRAN water accounting programs that have been used by Reclamation to account for the delivery, use, and storage of SJ and Rio Grande (RG) waters within the basin.

- The Planning Model (just beginning development) is an offshoot of the Water Operations Model and will be used as a predictive model for planning and multiple scenario runs and will be an important tool for the Upper Rio Grande Water Operations Review and Environmental Impact Statement (URGWOPS) studies. The number of SJ contractors in the model will be reduced to make running long periods of analysis (20-30 years) more efficient and timely and additional rules will be developed to allow more alternatives.

- The Forecast Model is designed to develop runoff daily hydrographs for portions of the basin; these hydrographs are based upon March – July volumetric forecasts developed by the Natural Resource and Conservation Service (NRCS) for various points within the basin. These hydrographs are exported to the Water Operations, and Accounting Models in order to assist in projecting future operations and aid in planning the movement of both SJ-C and native (RG) water throughout the system. The Forecast Model also sets data for other slots, such as diversions, wastewater returns, drain flows, precipitation, etc., for use in the Water Operations, and Accounting Models.

The Forecast Model is a rather simple way of forecasting future values based on historical data. It is expected that some of the functionality of the Forecast Model will be replaced in the future with more sophisticated or scientific methods of forecasting such as with the USGS Modular Modeling System (MMS) or the Corps Water Management System (CWMS).

The purpose of this document is to describe the procedures used for setting up the Forecast model for running, testing and validating the Forecast module of URGWOM, as well as discuss the results obtained during this phase of testing. Included in this document are a description of the methods used in the development and operation of this module, a brief description of the NRCS runoff forecasts, descriptions of the testing methods and suite of tests used to validate this module, and a summary of the results of the testing suites conducted.

NOTE: This document does NOT test the accuracy of the NRCS Streamflow Forecasts, it merely verifies that the Forecast models' disaggregation of the NRCS runoff period volumes to daily hydrographs are correct.

2.0 Description of Runoff Forecasts and Forecast Model

NRCS Snowmelt Runoff Forecasts

Much of the information in this sub-section was quoted and paraphrased from the foreword to the NRCS Western US Water Supply Outlook Report, which can be viewed at http://www.wcc.nrcs.usda.gov/water/quantity/foreword.html.

Each year, the NRCS publishes a monthly series of reports summarizing the water supply outlook for each of the Western states, as well as that of the Western United States region. The water supply outlook for each of the Western States is published during the first week of each month that a report is issued and typically contains a streamflow forecast for the upcoming spring runoff, a summary of the snow accumulation to date, and a reservoir summary for larger reservoirs in the area. These Outlook Reports are released for each month from January through May or June, depending on the state itself. For example, the snowmelt and spring runoff patterns in Montana and Idaho warrant reports through June, while the snowmelt and spring runoff patterns in New Mexico warrant reporting through May only.

Most of the usable water in the western states originates as mountain snowfall. This snowfall accumulates during winter and spring, several months before the snow melts and appears as streamflow. Since the runoff from precipitation as snow is delayed, estimates of snowmelt runoff can be made well in advance of its occurrence. Fall precipitation influences the soil moisture conditions prior to formation of the snowpack and explains, in part, the effectiveness of the snowpack in producing runoff.

The forecasts of natural runoff in the NRCS Outlook Reports are based principally on measurements of precipitation, snow water equivalent, and antecedent runoff. Forecasts become more accurate as more of the data affecting runoff are measured. All NRCS forecasts assume that climatic factors during the remainder of the snow accumulation and melt season will interact with a resultant average effect on runoff. Because of this assumption, early season forecasts are subject to a greater change than those made on later dates. Runoff forecasts within the NRCS Outlook Reports are listed for what the NRCS terms "forecast points." Forecast points chosen by the NRCS are typically locations such as well-known gaging stations, reservoir inflows, or larger tributary inflows into major river reaches. The streamflow forecasts themselves are typically reported as runoff volumes, in thousands of acre-feet, for the spring runoff season, which for most forecast points in New Mexico are the months of March through July. For example, a typical Outlook Report for New Mexico might list a March through July runoff volume at the Otowi gage on the Rio Grande as "1,250". This would mean that the total volume of unregulated streamflow that is forecast to flow by this gage in the months of March through July is 1.25 million acre-feet. A portion of a typical outlook report for New Mexico can be seen in Table 1.

Precipitation and snowfall accumulation of known probability as determined by analysis of past records are utilized in the preparation of probability runoff forecasts. The forecasts include an evaluation of the standard error of the prediction model. The forecast runoff volumes are presented at three levels of probability as follows:

Most Probable Forecast: Given the current hydrometeorological conditions to date, this is the best estimate of what the actual runoff volume will be this season. This is the seasonal runoff that has a fifty (50) percent chance of exceedance.

Reasonable Maximum Forecast: Given current hydrometeorological conditions, this seasonal runoff volume has a ten (10) percent chance of being exceeded.

Reasonable Minimum Forecast: Given current hydrometeorological conditions, this seasonal runoff volume has a ninety (90) percent chance of being exceeded.

Adjustments: Runoff forecasts at all points are for full natural or unimpaired runoff corrected for evaporation, upstream diversions, and adjusted for other hydrologic changes as they are developed. Reference should be made to the U.S. Geological Survey (USGS) water supply papers for detailed information concerning diversions and adjustments at the various forecast points. For this reason, NRCS snowmelt runoff forecasts are often referred to as "Unregulated Runoff Forecasts."

Table 1 – A portion of a typical NRCS Water Outlook Report for New Mexico

RIO GRANDE BASIN
Streamflow Forecasts - April 1, 2000

Forecast Pt	<=== Drier ===	Future Conditions		=== Wetter ===>			
	============== Chance of Exceeding * ==============						
Forecast Period	90% (1000AF)	70% (1000AF)	50% (Most Prob) (1000AF)	(% AVG.)	30% (1000AF)	10% (1000AF)	30-Yr Avg (1000AF)
El Vado Reservoir Inflow							
MAR-JUL	63	80	112	50	144	190	223
APR-JUL	57	72	101	49	130	173	206
Rio Grande at Otowi Bridge							
MAR-JUL	186	241	330	48	489	723	686

* 90%, 70%, 30%, and 10% chances of exceeding are the probabilities that the actual volume will exceed the volumes in the table.

The average is computed for the 1961-1990 base period.

(1) - The values listed under the 10% and 90% Chance of Exceeding are actually 5% and 95% exceedance levels.

(2) - The value is natural volume - actual volume may be affected by upstream water management.

URGWOM Forecast Model

The Forecast model is designed to develop snowmelt-runoff daily hydrographs for portions of the Rio Grande Basin; these hydrographs are based upon March – July (April-July in the case of the San Juan River forecasts) volumetric forecasts developed by the Natural Resource and Conservation Service (NRCS) for various points within the basin. These daily hydrographs along with data for other slots, such as diversions, wastewater returns, drain flows, precipitation, etc., are exported to the Water Operations, Accounting and Planning Models in order to assist in projecting future operations and aid in planning the movement of both SJ and RG water throughout the system.

The model has as input each of the historical data parameters needed for the other models for the period of 1985 through 1996. This historical data is used to project future hydrology and data inputs for the other models. When other periods of historical data for each of the parameters is available, the model can be updated to be include a larger data set to provide a greater sample of climatically related data.

The Forecast Model was developed using the RiverWare software program. It uses data objects to store the historical data and the computed forecasted data parameters. A RiverWare Rule Language (now RiverWare Policy Language) ruleset was developed to compute the forecasted parameters based on historical data. A workspace layout of the Forecast Model is shown in Figures 1 through 3.

Figure 1 shows the data objects that contain the historical data. The computed forecasted data are output to the data objects shown in Figure 2. Figure 3 shows the reach objects and reservoir objects that contain flows and RG storages that have occurred up to the date of the forecast run. The data in the objects in Figure 3 will be explained in later paragraphs.

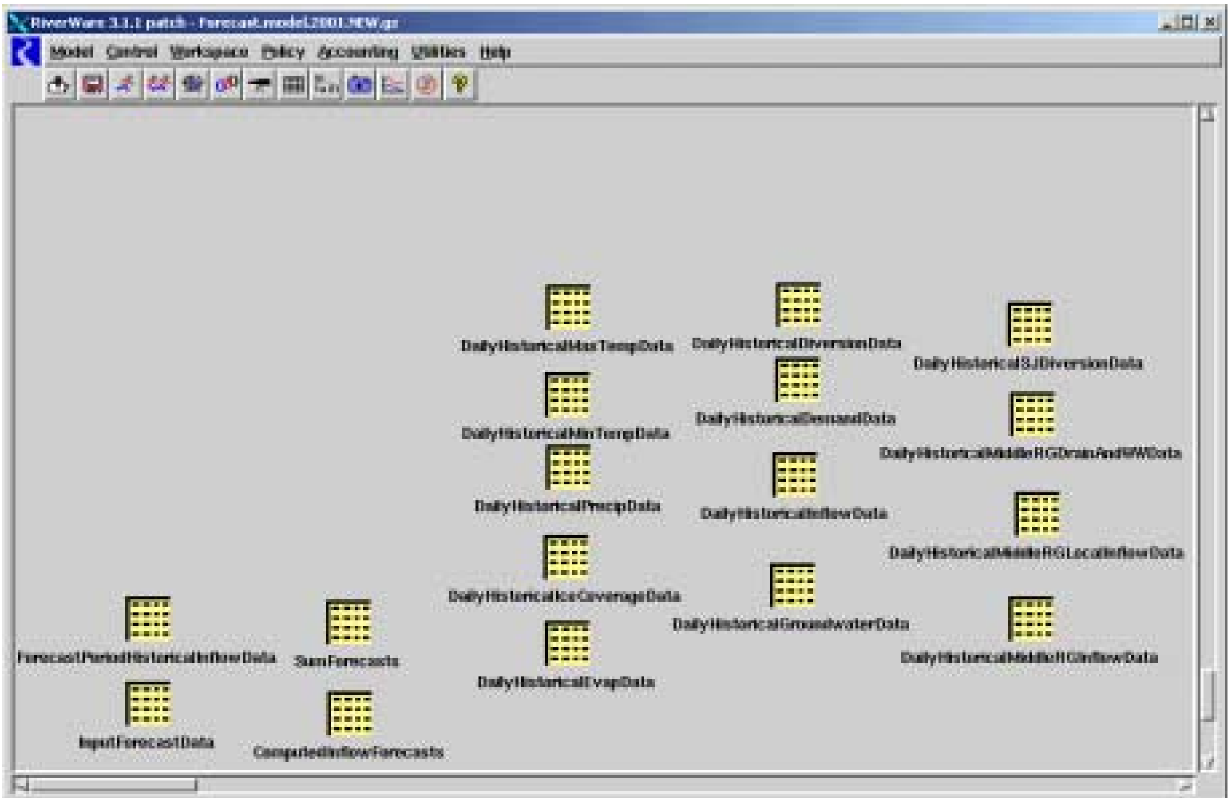


Figure 1 - Forecast Model Workspace Layout - Historical Data Objects.

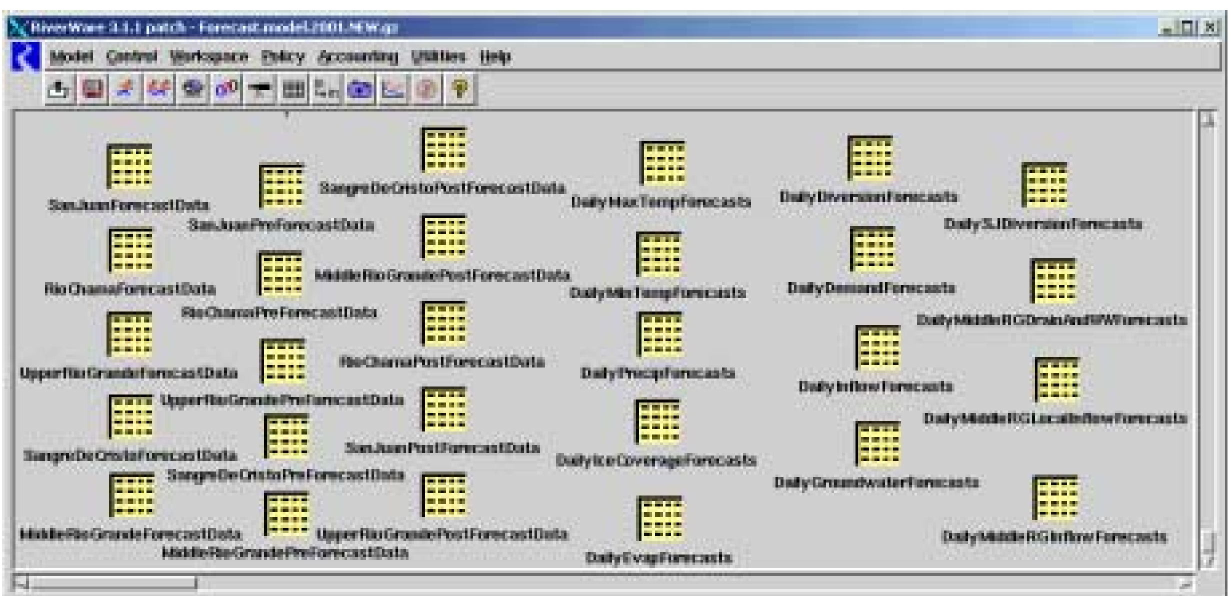


Figure 2 - Forecast Model Workspace Layout - Forecast Data Objects

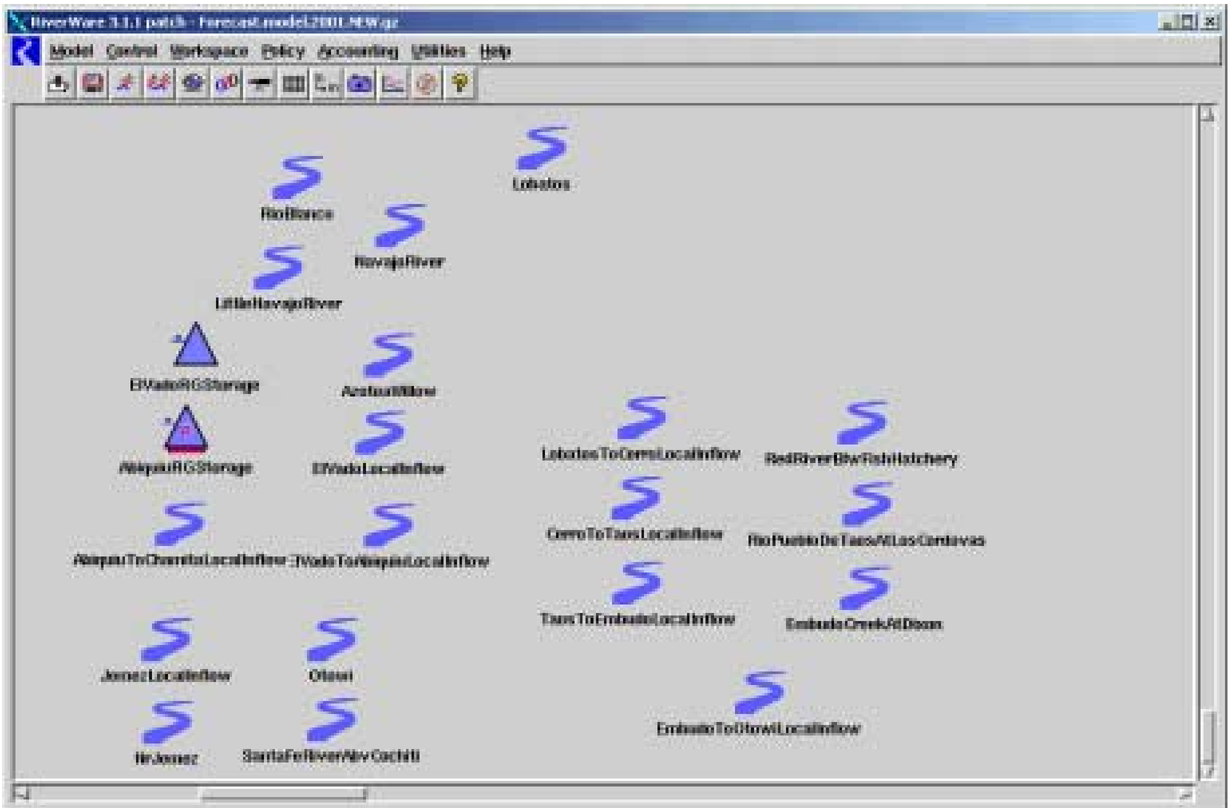


Figure 3 - Forecast Model Workspace Layout – Rio Grande Storage and Point Inflow Objects

Figure 4 shows the Input Forecast Data object when it is opened, displaying the slots (table slots) that have been filled or need to be filled when preparing a forecast run. Input for this model includes the NRCS forecasted runoff volumes for eleven (11) forecast points, the number of years to average parameters during snowmelt-runoff period, the distribution of runoff and local inflow within the snowmelt runoff, coefficients and constants for the linear regression equation which relates the runoff on the Little Navajo River to that of the Navajo River, average losses for the runoff period, the starting date of forecasts, the blending ratio, the number of years to be average parameters during the pre-forecast period, and the number of years to average parameters during the post-forecast period. All of this data can be input into slots set up in the model, as seen in Figure 4.

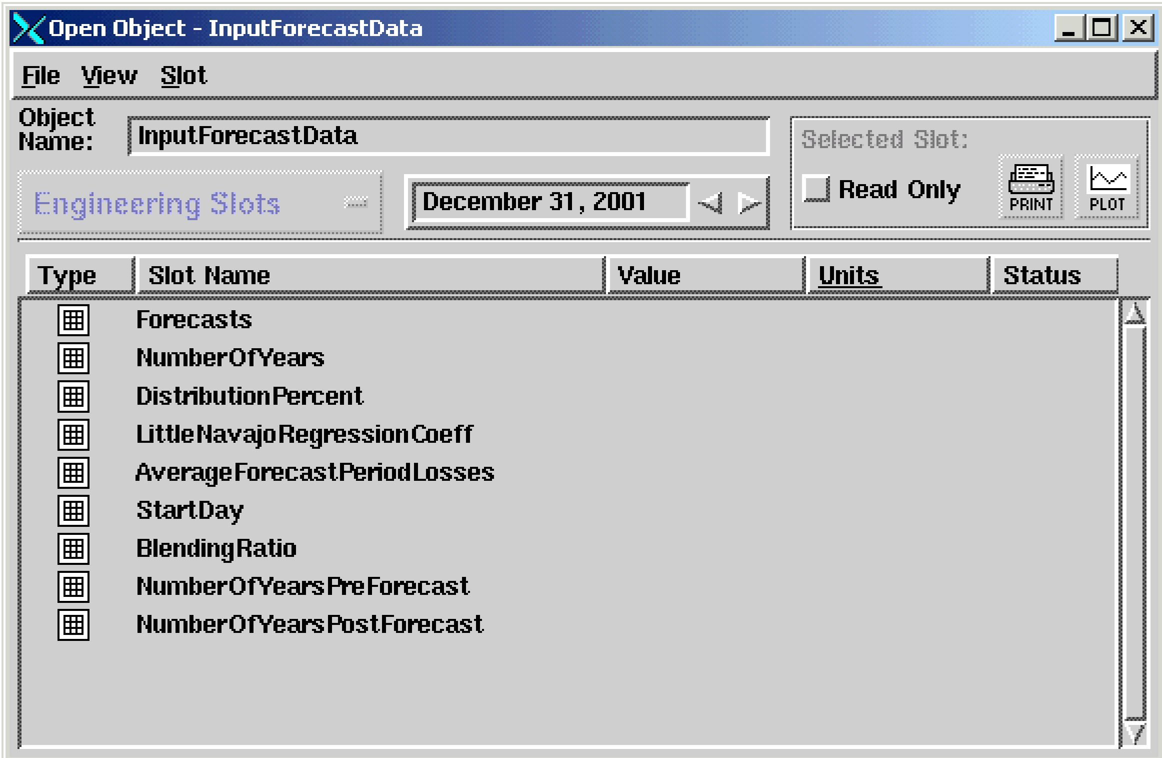
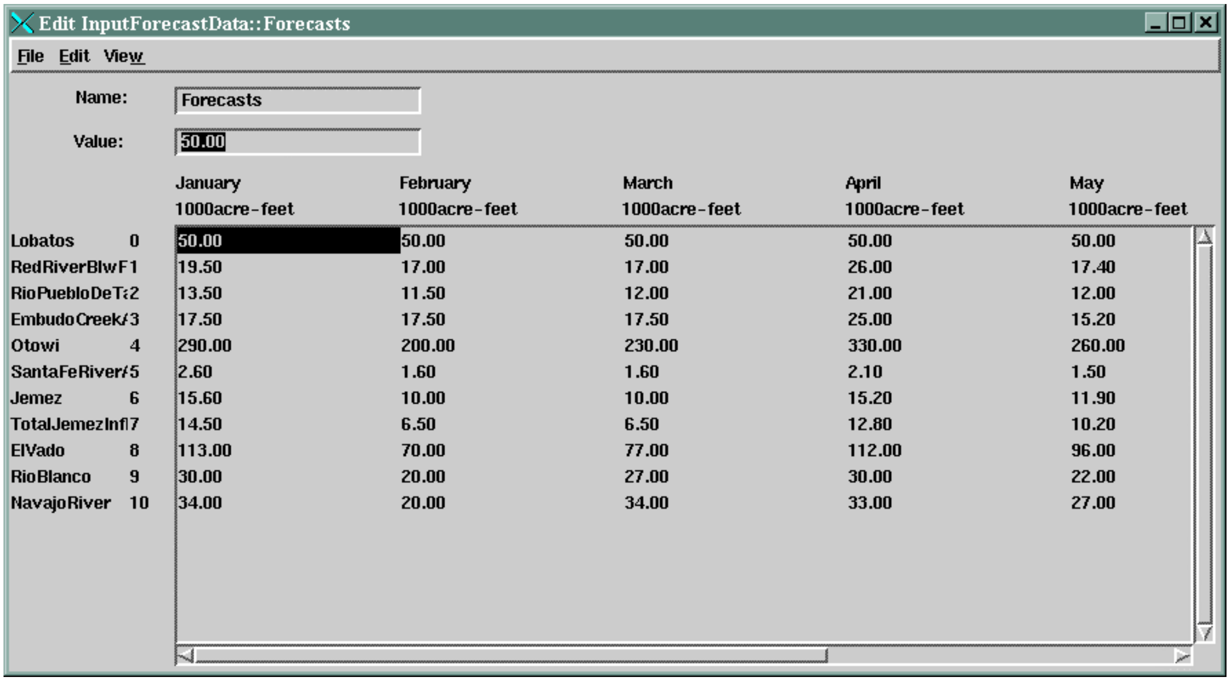


Figure 4 – Input slots for Forecast Model

Before going any further, it is important to examine the required input data shown in Figure 4 in greater detail. This discussion and the following description of the model are intended to be brief, yet still provide an adequate description of the workings of the Forecast Model. The Forecast Model's ruleset contains the logic used.

A maximized view of the Forecasts slot shown in Figure 4 can be seen in Figure 5. This slot takes the shape of a table with five columns and eleven rows for data entry.



Edit InputForecastData::Forecasts

File Edit View

Name: Forecasts

Value: 50.00

		January 1000acre-feet	February 1000acre-feet	March 1000acre-feet	April 1000acre-feet	May 1000acre-feet
Lobatos	0	50.00	50.00	50.00	50.00	50.00
RedRiverBlwF	1	19.50	17.00	17.00	26.00	17.40
RioPuebloDeT	2	13.50	11.50	12.00	21.00	12.00
EmbudoCreek/	3	17.50	17.50	17.50	25.00	15.20
Otowi	4	290.00	200.00	230.00	330.00	260.00
SantaFeRiver/	5	2.60	1.60	1.60	2.10	1.50
Jemez	6	15.60	10.00	10.00	15.20	11.90
TotalJemezInfl	7	14.50	6.50	6.50	12.80	10.20
ElVado	8	113.00	70.00	77.00	112.00	96.00
RioBlanco	9	30.00	20.00	27.00	30.00	22.00
NavajoRiver	10	34.00	20.00	34.00	33.00	27.00

Figure 5 – Input data required for the Forecast slot within the Input Forecast Object contained in the Forecast Model

With the exception of Row 0 - Lobatos, the rows within this table list forecast points used by the NRCS in their runoff forecasts. The data entered into the Lobatos cell will be provided by the State of Colorado and represents their projected Rio Grande Compact deliveries to the New Mexico state line. Each column represents the monthly NRCS forecast issued for the particular year that the model is examining. The data contained in this slot is updated as each new forecast is issued. After the updated data is entered within the model, the model is run again in order to update the projected runoff hydrographs.

Two of the forecast points listed in Figure 5 are recent additions to the NRCS reporting system. The forecast point listed in row 3 of Figure 5, Embudo Creek at Dixon, was added in 1999 at the request of the URGWOM steering committee. In addition, the NRCS added the forecast point listed in row 7 of Figure 5, Jemez Reservoir Inflow, in 1998.

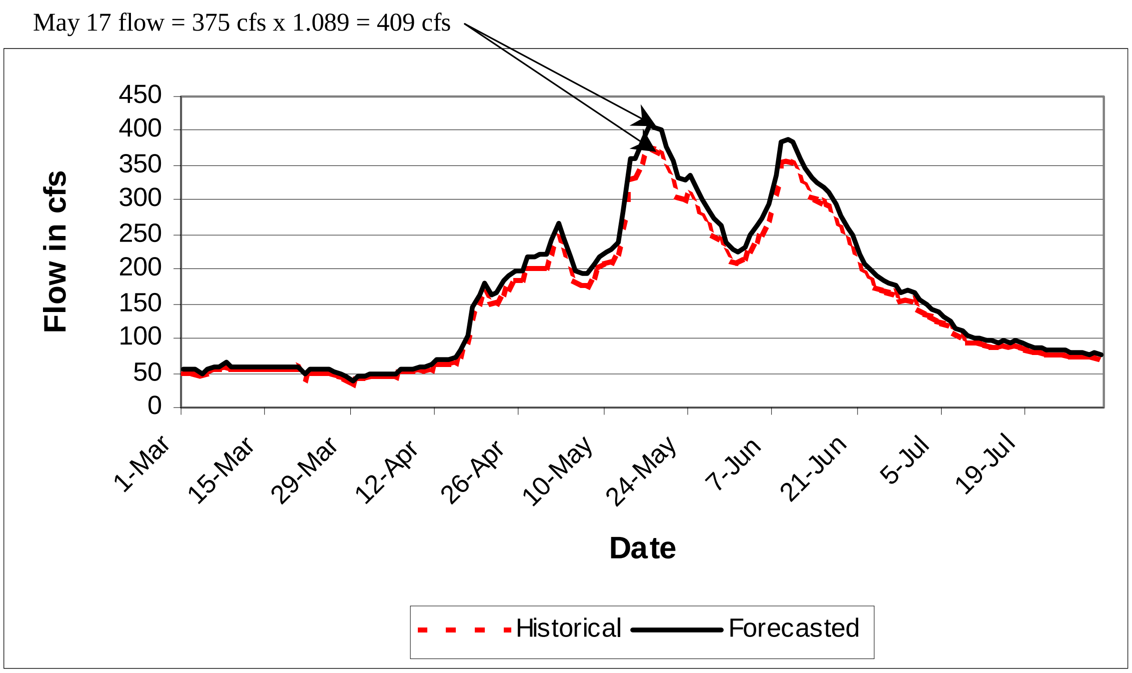
A maximized view of the Number of Years slot listed in the Input Forecast Data slot is shown in Figure 6. This slot contains a thirteen row by five column data table. The rows are labeled with physical variables that the model uses to generate runoff hydrographs. The columns break down the data into the five basins affecting runoff and operations within the Rio Grande Valley. The data entered into this table is best described by the slot's title "Number of Years." The user enters a value from one (1) to the number of years (currently up to twelve years can be selected) of historical data into each of the table's cells. This entry represents the number of closest years of each of these physical parameters the model will use to generate a runoff hydrograph and other parameters. In other words, if the user enters a value of 1 in the (Max Temp, Rio Chama) cell, the model will pull up the closest year of maximum temperature data from the model's database and use this data to assist in simulating runoff conditions within the Rio Chama basin. However, if the user were to enter a value of 3 into this cell, the model would pull up the closest three years (as determined by the runoff forecasts) of maximum temperature data from the database, average the values each day, and use the results to simulate runoff conditions within the Rio Chama basin.

Note that the term "closest year" refers to the year contained in the database whose forecasted runoff volume data most closely matches that of the year currently being simulated by the model. The "Set Closest Year" Rule makes use of the NumberOfYears slot's input to generate the desired data.

The concept of the "closest year" and disaggregating the NRCS runoff period volume to daily flows should be explained at this point. The NRCS forecast volume is compared with historical hydrograph volumes over the same forecast period (March-July) to determine which historical year is the closest to then use as a "template" or "unit" hydrograph to generate daily flows. The assumption used in this approach is that a year which had a similar amount of volume to the current forecast, is a fair starting point on the expected manner in which the forecasted volume will runoff this time. The shape of the closest year hydrograph is then used to disaggregate the total volume of the forecast to daily flows. Of course the forecasted volume will not exactly match any historical volumes, so the historical daily flows are adjusted by the ratio of the forecasted volume to the historical volume, in order to match the forecasted volume for the period. If more than one closest year is selected, the model averages the values for each day of the closest years and then adjusts the resulting values to match the forecasted volume. An example of adjusting the historical hydrograph to match the forecasted volume is shown in Figure 6.

The user also has the ability to manually select the closest year(s) (overriding the rule) because they may prefer other historical hydrograph shapes rather than the one that is closest in volume. This is done by inputting the desired year in the Forecast Data objects shown on the left side of Figure 2.

The NumberOfYears table is to set the number of years to average for the forecast period (March-July). Two similar tables (NumberOfYearsPreForecast and NumberOfYearsPostForecast) also require input to set the number of years before (January-February) and after (August-December) the forecast period. These tables are set up in the same manner as the table in Figure 7.



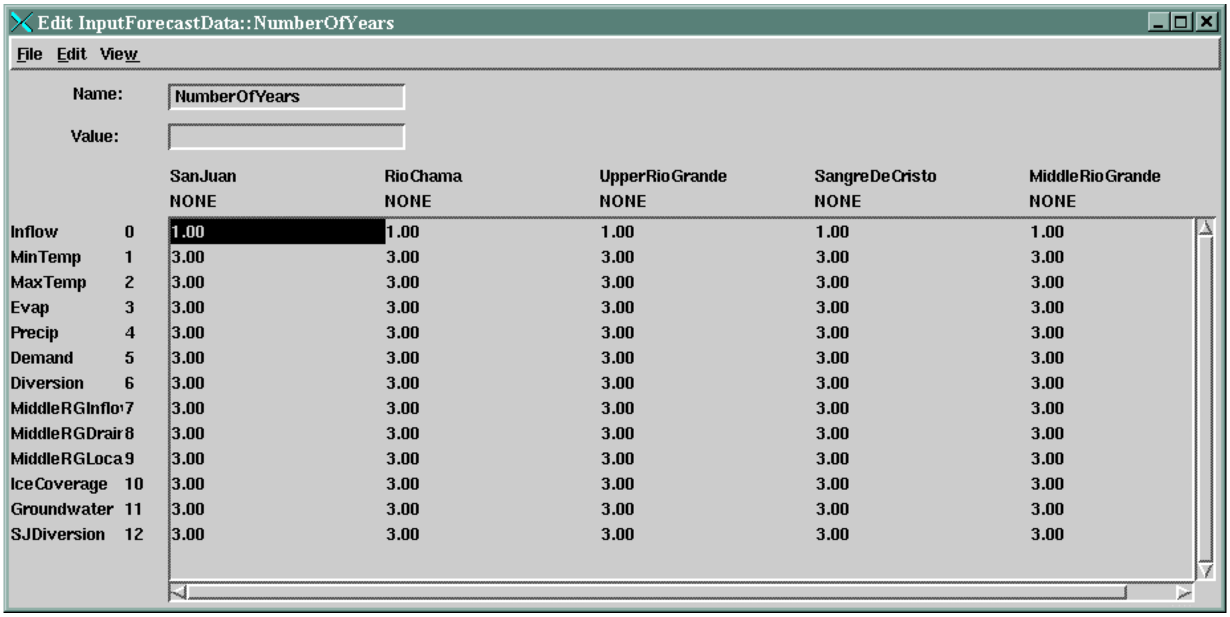
Mar-July Forecasted Volume = 50,000 acre-feet

Mar-July Historical Volume =45,913 acre-feet

Ratio = 50,000/45,913 = 1.089

Forecasted flow = Historical flow x Ratio

Figure 6 – Example of Adjusting Historical Hydrograph to Match Forecasted Volume



Edit InputForecastData::NumberOfYears

File Edit View

Name: NumberOfYears

Value:

		SanJuan	RioChama	UpperRioGrande	SangreDeCristo	MiddleRioGrande
		NONE	NONE	NONE	NONE	NONE
Inflow	0	1.00	1.00	1.00	1.00	1.00
MinTemp	1	3.00	3.00	3.00	3.00	3.00
MaxTemp	2	3.00	3.00	3.00	3.00	3.00
Evap	3	3.00	3.00	3.00	3.00	3.00
Precip	4	3.00	3.00	3.00	3.00	3.00
Demand	5	3.00	3.00	3.00	3.00	3.00
Diversion	6	3.00	3.00	3.00	3.00	3.00
MiddleRGInflo	7	3.00	3.00	3.00	3.00	3.00
MiddleRGDrair	8	3.00	3.00	3.00	3.00	3.00
MiddleRGLoca	9	3.00	3.00	3.00	3.00	3.00
IceCoverage	10	3.00	3.00	3.00	3.00	3.00
Groundwater	11	3.00	3.00	3.00	3.00	3.00
SJDiversion	12	3.00	3.00	3.00	3.00	3.00

Figure 7 - Input data required for the Number of Years slot within the Input Forecast Object contained in the Snowmelt Runoff Forecast Model

The Accounting Model may require data that is not readily available (such as diversion, wastewater, missing gage data) that must still be input into the Accounting Model to perform a run. The Forecast Model can be used to "fill-in" these parameters that are not yet available, but are realistic estimates to allow the Accounting simulation to run. The "Pre Forecast" rules allows the Forecast Model to fill-in data prior to the forecast period based on the latest forecast (e.g., the Forecast Model run is set up to run a March NRCS forecast, that is significantly different than the February forecast, thus the Pre Forecast rules will fill-in data for January and February based on the new forecast). If the user is not concerned with generating data prior to the date of the forecast, simply begin the run on the date of the forecast (e.g., set the Start time of the run for the March forecast to begin on March 1).

The Forecast Model can also generate forecasts of data parameters for the period after the NRCS forecast period of March-July, using the "Post Forecast" rules to generate the data for the August-December period. The Pre and Post Forecast rules do not adjust the daily flows, they simply use the actual historical data (or average if more than one closest year) as the forecasted data.

Note that the user has been given a fair amount of flexibility to generate forecasted data for several periods throughout the year. This requires the user understand the model and the needed input to achieve the desired results.

A maximized view of the Distribution Percent slot contained within the Input Forecast Object is shown in Figure 8. Unlike the other slot titles contained in the Input Forecast data object, the significance of the data contained in this slot may not be readily apparent. Although one of the major goals of this report is to be as brief as possible, the logic and programming statements that utilize this data do need to be explained so that the reader may fully understand how the data contained in this slot is used. Much of the following explanation was taken from programming comments written by Brad Vickers, of Wave Engineering, and is in the Rules code. Note that some rules have been added (such as the PreForecast and Post Forecast rules and functions) and slightly modified by the URGWOM technical team since the programming comments were written by Wave Engineering, that have not been noted and some programming comments require updating. The following discussion will focus on the "Distribute Forecasts" Rule and will ultimately explain the significance of the data located in the Distribution Percent slot.

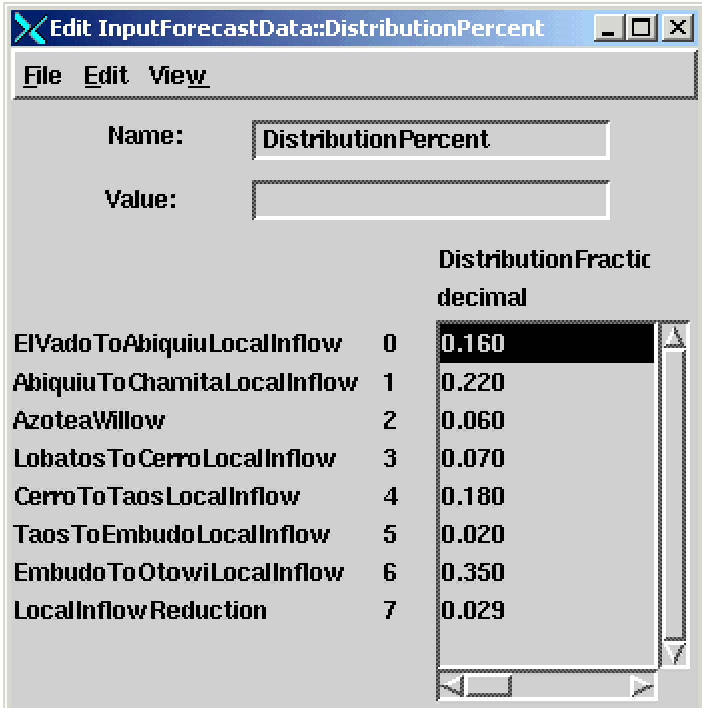


Figure 8 - Input data for the Distribution Percent slot within the Input Forecast Object contained in the Forecast Model

Although the user inputs data for eleven NRCS forecast points into this model, nineteen forecast points are needed in order to successfully run the Water Operations Model. This transformation takes place within the “Distribute Forecasts” Rule. This rule uses the information in the Input Forecasts slot to determine the total Mar-July forecast for each of the nineteen locations needed by the Water Operations Model. This particular rule also uses the input forecast for the Navajo River and Rio Blanco forecast points to determine a projected runoff volume and its distribution for the Little Navajo River, which is not currently forecasted by the NRCS. One of the purposes of this rule is to split the forecast of El Vado Reservoir Inflow into two components: (1) Rio Grande inflow into Heron Reservoir (which is assumed to be released into El Vado, because storage of water native to the Rio Grande Basin is not allowed to be stored in Heron); and (2) the local inflow, or runoff, between Heron and El Vado Reservoirs plus additional snowmelt runoff originating in the Rio Chama Basin. After dividing the El Vado Inflow into two components, the logic contained in the rule then forces the model to determine the total local inflow within the Rio Grande Basin and distributes it into six locations. These six locations, as they are referred to in the model, are:

LobatosToCerroLocalInflow,
CerroToTaosLocalInflow,
TaosToEmbudoLocalInflow,
EmbudoToOtowiLocalInflow,
AbiuiuToChamitaLocalInflow,
and ElVadoToAbiquiuLocalInflow.

These operations and calculations within the model provide the needed nineteen inflow points for export to the Water Operations Model.

In order to explain the significance of the Distribution Percent slot, one other method must be explained in greater detail. Within the Rio Grande basin above Otowi, the NRCS or the state of Colorado provide forecasts of inflow for five locations: Lobatos, RedRiver Below the Fish Hatchery, Rio Pueblo De Taos

Near Los Cordovas, Embudo Creek Near Dixon, and El Vado Reservoir Inflow. Along with these forecast points, a projected runoff volume at Otowi is provided by the NRCS. Thus, the portion of runoff that enters the system between these forecast points and Otowi can be indirectly computed. In order to compute the total contribution that this “local inflow” has on the forecast of flow at Otowi, each of the provided forecasts must be routed (inclusive of model losses) to Otowi. In the Water Operations model, these losses vary monthly. However, losses in the forecast model use the average of the March-July percent losses in the Water Operations Model to estimate these losses. In order to compute the total Rio Grande local inflow above Otowi, the routed forecasts are subtracted from the Otowi forecast according to the relationship:

Total Local Inflow = (ForecastAtOtowi - routed(ForecastAtElVado) - routed(ForecastAtLobatos) -
routed(ForecastAtRedRiver) - routed(ForecastAtRioPueblo) -
routed(ForecastAtEmbudoCreek)) X adjustment factor

An adjustment factor in the above equation is needed to compensate for the difference in losses between the monthly losses applied in the Water Operations model and the average losses applied with this model. This adjustment factor was determined via analysis to be approximately 2.9 percent.

After the total local inflow above Otowi is determined, the amount to distribute to each of the six locations is computed by multiplying the total local inflow by the factors located within the Distribution Percent slot shown in Figure 8. These distribution factors were determined by analyzing the historical flow similar to the procedure used in splitting the El Vado Reservoir forecast. After the distribution is determined, each forecast of local inflow is then routed back upstream (adding losses back in). The net effect of this procedure is to produce a forecast closely matching (within two tenths of a percent) the forecasted flow at Otowi, issued by the NRCS. The detail and the specifics of how each forecast or local inflow is routed using the following functions is in the ruleset:

TotalLocalInflowForecast
RoutedRioChamaForecast
RoutedRioGrandeForecast
RouteLobatosToCerroLocalInflow
RouteCerroToTaosLocalInflow
RouteTaosToEmbudoLocalInflow
RouteEmbudoToOtowiLocalInflow
RouteAbiquiutoChamitaLocalInflow
RouteElVadoToAbiquiuLocalInflow

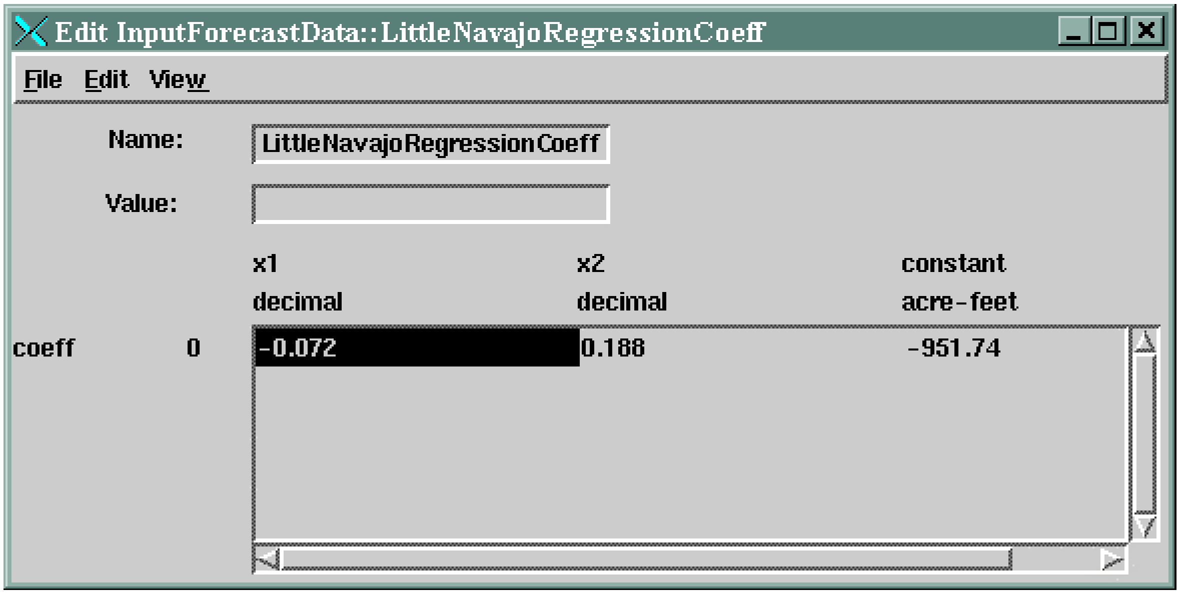


Figure 9 - Input data for the LittleNavajoRegressionCoeff slot within the Input Forecast Object contained in the Forecast Model

A maximized view of the Little Navajo Regression Coefficient is shown in Figure 9. The Little Navajo River at the Little Oso Diversion Dam is not presently included in any runoff forecast. However, there is a very strong relationship between the flow of the Navajo River and Rio Blanco to the flow in the Little Navajo River. A regression analysis done by the URGWOM technical team yielded a correlation coefficient of 0.96 for this relationship. The regression coefficients and constant obtained in this study are located in the Little Navajo Regression Coeff slot shown in Figure 9. These coefficients are used in the function “LittleNavajoForecast” to determine the forecast for the Little Navajo River. This function represents the relationship

Mar – Jul Runoff Volume for Little Navajo near Little Oso Diversion Dam =
-0.072 (Rio Blanco Mar – Jul Runoff Vol for Rio Blanco abv Blanco Div Dam)
+ 0.188 (Navajo River Mar – Jul Runoff Vol for Navajo River abv Oso Div Dam) – 951.74

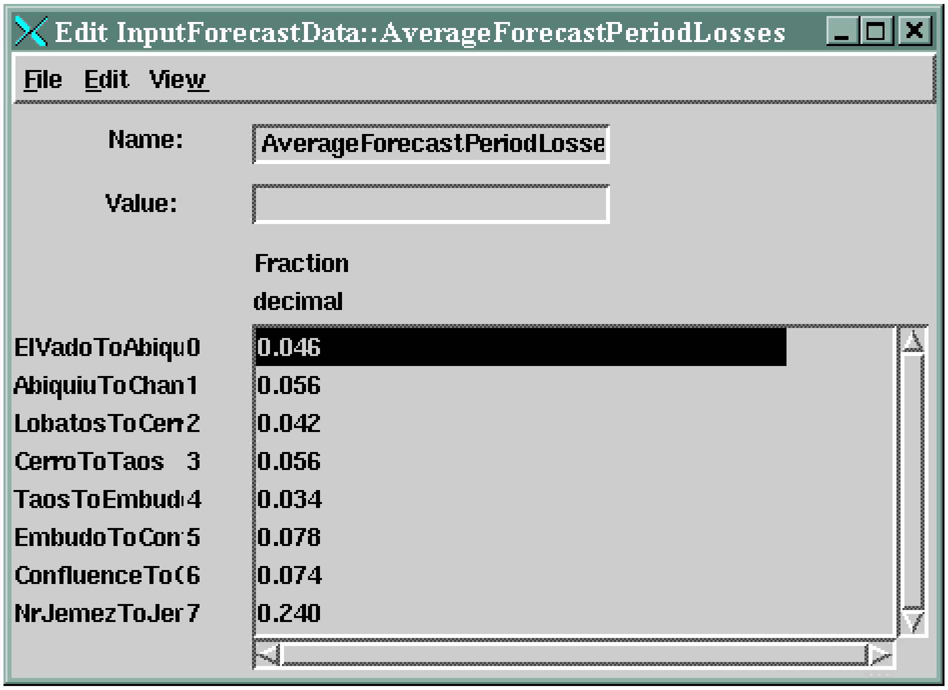


Figure 10 - Input data for the Average Forecast Period Losses slot within the Input Forecast Object contained in the Forecast Model

A maximized view of the Average Forecast Period Losses slot is shown in Figure 10. As stated earlier, projected runoff volumes are routed from the forecast points north of Otowi to the Otowi forecast point. During the runoff season of March through July, these losses are averaged within the Forecast Model. These average losses are entered in the Average Forecast Period Losses slot seen in Figure 10 and are used to route flows within each of these seven reaches. Row seven (7) of the data table comprising this slot is used to compute additional losses and inflow between the forecast points of Jemez River near Jemez and Jemez Reservoir Inflow.

A maximized view of the Start Day slot can be seen in Figure 11. The data table in this slot consists of a one row by one column series and is fairly self-explanatory. The start day of the monthly forecast is entered into this slot. At present, RiverWare requires that date references be in the form of the Day of the Year (DOY). The DOY for any day of a particular year is simply the numerical order of that day in that year. For example, January 1 of any year would have a DOY of 1. During a non-leap year, March would have a DOY of 60. However, during a leap year, March 1 would have a DOY of 61. During a run of the Forecast Model, the run control is usually kept at a start time of January 1 (Figure 11A). However, the value input into the Start Day slot does have a direct bearing on which NRCS monthly forecast data are used in the model run. This may sound a bit confusing, so an example might be the best way to clarify this distinction.

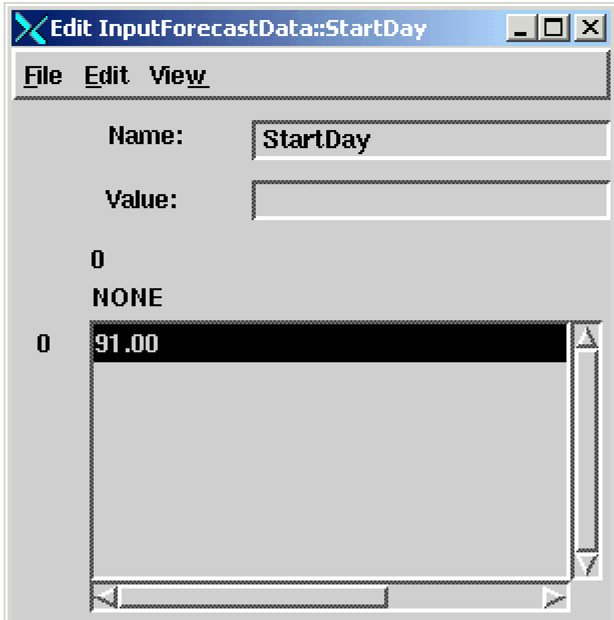


Figure 11 - Input data required for the Start Day slot within the Input Forecast Object contained in the Snowmelt Runoff Forecast Model

Figure 11A - Run Control Dialog Box for the model run associated with the Start Day slot shown in Figure 11

Let's say that a user is attempting to use the model to project runoff hydrographs using the April 1 NRCS forecast. The user sets the Start Day slot to 91 (see Figure 11, for a non-leap year), and sets the Run Control from January 1 through December 31 (see Figure 11A).

A few other items must also be updated before the user can start the model run. As stated earlier, the three modules of URGWOM exchange information between each other, with each module interdependent on the other two for critical information. In this case, the Accounting Model must be updated to input the Rio Grande storages (to compute the amount of RG runoff stored in the reservoirs) through the forecast date, April 1 in this case, prior to running the Forecast Model. Once the Accounting Model is updated and compiled, its results are imported into the Forecast Model by invoking the "UpdateRGStorage" DMI shown in Figure 11B. Since Reservoir objects are used for computing the RG runoff captured by El Vado and Abiquiu, initial RG storages must always be input. Otherwise the simulation will abort because the initial conditions of the reservoir objects will not be known.

Also, since our forecast run has a beginning date of April 1, the actual flow values from January 1 through March 31 must also be imported into the Forecast Model, to determine the amount of runoff that has already occurred up to the date of the forecast. This information is required to determine the amount of runoff volume remaining through the rest of the forecast period (April-July). Importing of actual flows up to the date of the forecast is done by invoking the "UpdatePointInflow" DMI also shown in Figure 11B.

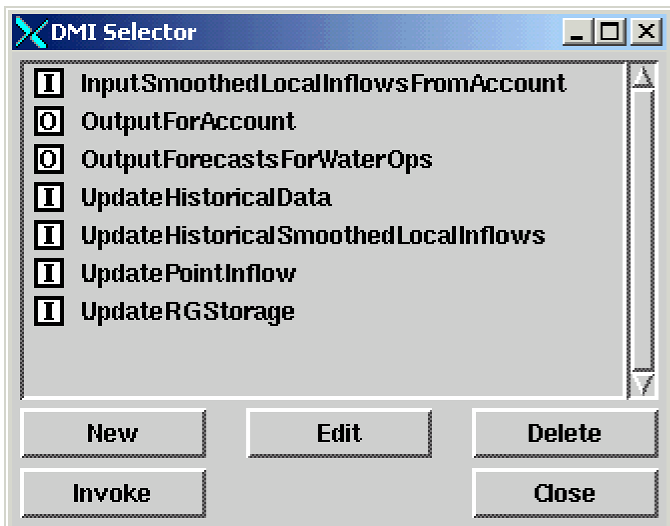


Figure 11B - Data Management Interface (DMI) Selector for the model run associated with the Start Day slot shown in Figure 11

The UpdateRGStorage and UpdatePointInflow Dmi's import data into the reservoir and reach objects that are shown in Figure 3.

Leap years can present a small annoyance to the results of the Forecast model. When forecasting during a leap year and the closest year selected was a non-leap year, the daily data will be offset by one day when comparing to the historical data. The same can also occur when forecasting during a non-leap year and the closest year selects a leap year. The user should be aware that this can happen. The volumes of the runoff forecasts are not affected by this phenomenon, just the timing of the daily flows are offset by one day.

While experimenting with the first few versions of the Forecast Model, users found that some of the local inflow values imported from the Accounting Model and the database varied greatly on a daily basis. In addition, the values for local inflow would occasionally take on negative values. In order to minimize problems such as these, two new functions within the Accounting Model and two new DMI's within the Forecast Model were developed which allow the user to generate and import smoothed local inflows into the Forecast Model. These DMI's, "Input Smoothed Local Inflows From Account" and "Update Historical Smoothed Local Inflows," are also shown in Figure 11B.

A maximized view of the Blending Ratio slot can be seen in Figure 12. The Blending Ratio is a value ranging from 0 to 1.0 that can be determined and entered by the user. During the initial testing of the Forecast Model, users noticed that there was a discontinuity between the actual and modeled hydrographs occurring on the first day of the simulation. In order to give the user the option of modifying this jump from a picture of the actual system to a forecasted picture of the system, the concept of the blending forecasted flows with observed flows was introduced.

The Blending Ratio allows the user to specify at which point the ratio of the forecasted flow to the previous days observed flow is great enough to blend the hydrograph to reduce a big jump or decrease in flows. For example, a Blending Ratio of 0.50 tells the model to blend the hydrograph when the absolute value the ratio between the forecasted flow to observed flow is equal to or greater than 0.5. If this is true then the first two values of the forecasted flows are adjusted equally (1/3) each day until on the third day the flow is equal to the forecasted flow on the third day. For example (also shown graphically in Figure 11A), if the ratio the forecasted flow on April 1 (say 175 cfs) to the observed flow on March 31 (say 100 cfs) is greater than the blending ratio in the table (175-100/100 = 0.75 > 0.5), then implement the blending of hydrographs. The flow on April 3 is 200 cfs, so the difference of the flows on March 31, and April 3 is 100 cfs. The flow on April 1 will be increased by 33 cfs to 133 cfs, followed by another 33 cfs increase on the April 2 to 166 cfs, and on the third day the flow is 200 cfs that was forecasted for April 3. Using this blending approach does slightly alter original forecasted flows to match the total volume for the NRCS runoff period. Therefore, the forecasted daily flows may not sum up exactly to the total volume of the NRCS forecast. If the user does not wish to “blend” the hydrographs, simply turn off the Blended Hydrographs rule. The user has to weigh the importance of almost exactly matching NRCS runoff-period volume forecast or avoiding big jumps or decreases from the observed flows to the forecasted flows.

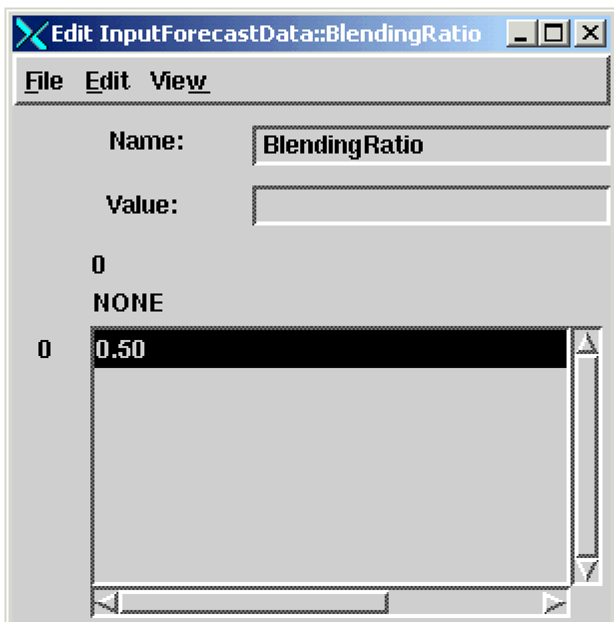


Figure 12 - Input data required for the Blending Ratio slot within the Input Forecast Object contained in the Forecast Model

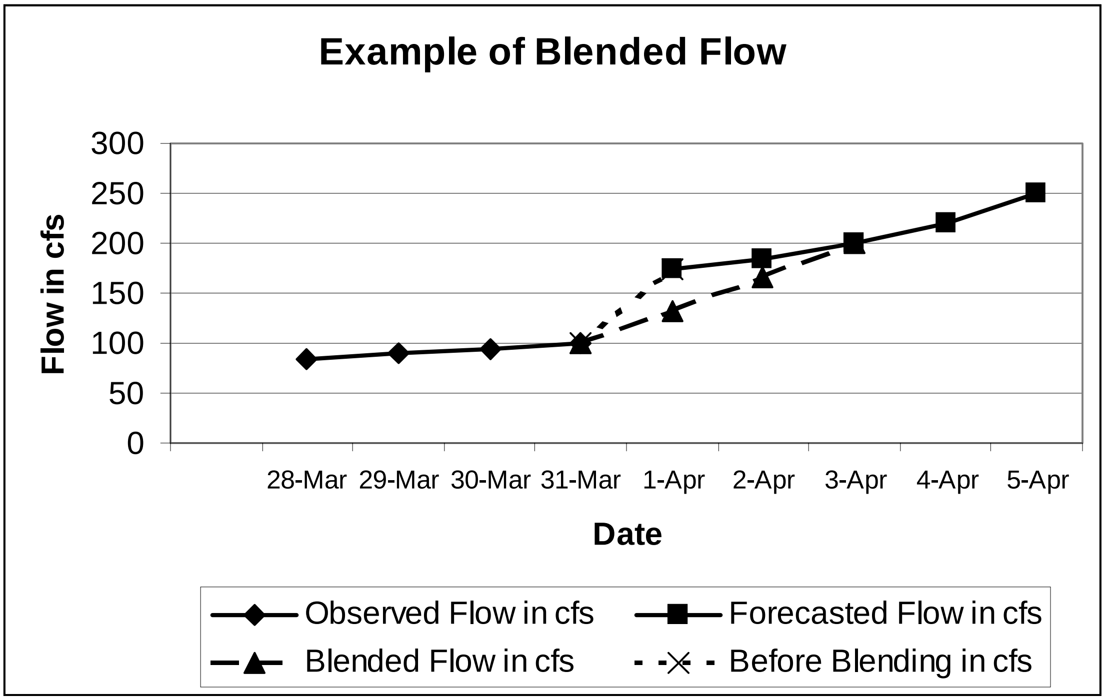


Figure 12A - Illustration of a Discontinuity Between Actual and Forecasted Flows

The Number of Years Pre Forecast and Number of Years Post Forecast slots are used in the same way the Number Of Years slot described earlier.
After setting and importing all of the required data for a Forecast Model simulation run, the user must load a ruleset for the model to compile. A ruleset is an aggregation of the operating logic and policy that affects the system modeled in RiverWare. In the case of the Forecast Model, the ruleset contains routing methods, loss rates, and data transformation methods and functions, just to name a few items. An example of the ruleset entitled “Forecast.ruleset” can be seen in Figure 13. The ruleset, like any other ruleset contained in a RiverWare model is loaded by simply clicking the “Ruleset Not Loaded” button in the upper right corner of the Ruleset Editor window.

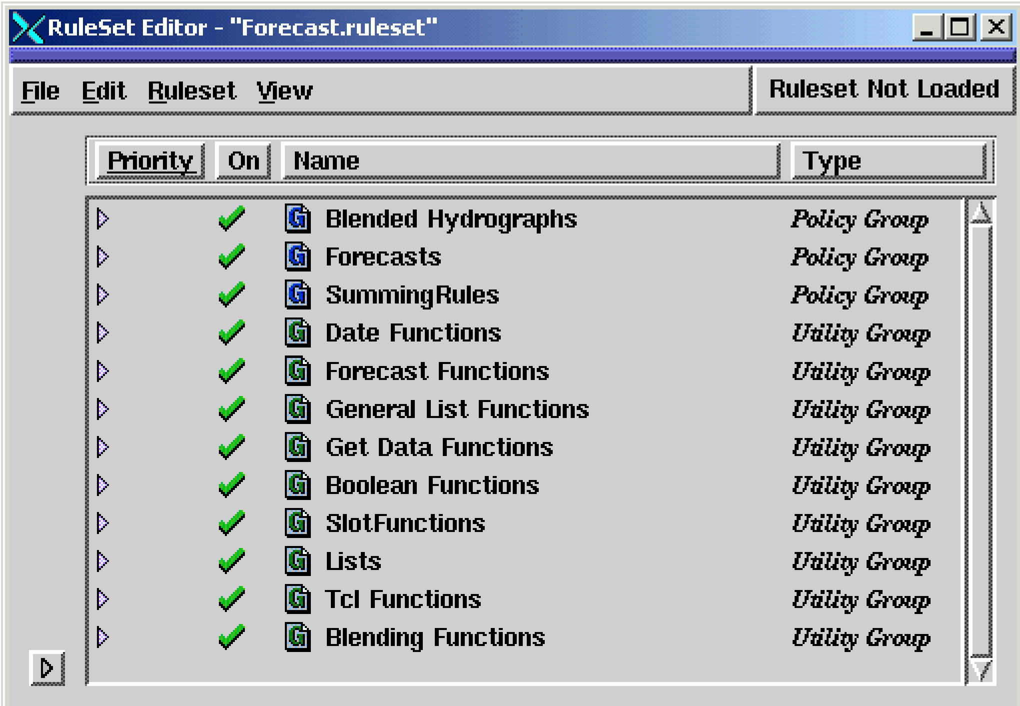


Figure 13 - A screenshot of the "Forecast.ruleset" used in the Forecast Model

Although one could write a much more in-depth and detailed description of this model, the purpose of this section was to give the reader a general idea of the functionality of the Forecast Model in a brief format.

3.0 Test Methods

The series of years from 1995 through 1998 was chosen as a study period to test the accuracy of the forecast model disaggregating the volume forecast to daily hydrographs. This period offered a fairly wide distribution of NRCS forecasted runoff volumes and was considered ideal for our purposes. Each of the monthly forecasts published by the NRCS for these years was used in the testing process, which resulted in a test set of twenty NRCS forecasts. In addition to using each of these twenty sets of data, each data set was run three times, using a different number of "similar year" values for each run. The testing matrix for this study is outlined in Table 2.

Table 2 – Proposed Testing Matrix for Validation of Forecast Model

Test Case	Year	Similar Years	Type of Snowpack	Number of Tests	Comment
1	1995	1	Avg	5 (Jan-May)	Test model for most probable runoff volume using the closest year for each NRCS forecast published that year
2	1996	1	Low	5 (Jan-May)	" "
3	1997	1	High	5 (Jan-May)	" "
4	1998	1	Avg to low	5 (Jan-May)	" "
5	1995	2	Avg	5 (Jan-May)	Test model for most probable runoff volume using the two closest years for each NRCS forecast published that year
6	1996	2	Low	5 (Jan-May)	" "
7	1997	2	High	5 (Jan-May)	" "
8	1998	2	Avg to low	5 (Jan-May)	" "
9	1995	5	Avg	5 (Jan-May)	Test model for most probable runoff volume using the five closest years for each NRCS forecast published that year
10	1996	5	Low	5 (Jan-May)	" "
11	1997	5	High	5 (Jan-May)	" "
12	1998	5	Avg to low	5 (Jan-May)	" "

Each of the eleven forecast points used in the model were used in this test, with the exceptions of Embudo Creek at Dixon, Jemez Reservoir Inflow, Lobatos and in some years Rio Blanco at Blanco Diversion, and Navajo River at Oso Diversion. As stated earlier, the forecast point, Embudo Creek at Dixon, was added to the NRCS forecast system this year. Because of this relatively new addition, an estimate of 10,000 acre-feet for the March – July runoff volume for this forecast point was used throughout the testing phase. In addition, the forecast point, Jemez Reservoir Inflow, was also a recent addition to the NRCS forecast. After discussing this particular forecast point with NRCS staff, an estimate of the March – July runoff volume to be input into the model for this forecast point was based on the relationship

Jemez Reservoir Inflow = Jemez River nr Jemez – Estimated Losses

Where Estimated Losses = 3,000 ac-ft in a low runoff year
5,000 ac-ft in a high runoff year

The forecast point, Lobatos, was held at a constant 50,000 acre-feet March – July volume for the purposes of this study.

The biggest effect of using estimated values for the two forecast points above Otowi (Lobatos and Embudo Creek at Dixon) is the impact on the local inflow forecasts above Otowi. By using estimated volumes at these two forecast points, the Local Inflows are adjusted up or down by the model to compensate for these estimates to match the forecast at Otowi.

4.0 Results

Tables 3 through 6 present a summary of the results of this study. The tables list NRCS forecasts and modeled forecasts for eight of the eleven forecast points used in the study. As stated earlier, two of the eleven forecast points required by the model were recently added to the NRCS reporting system. As such, methods for estimating these forecast points, Jemez Reservoir Inflow and Embudo Creek at Dixon, outlined in the previous section were used. Also, a constant March through July volume of 50,000 acre-feet was used for the Lobatos forecast point.

To test the Otowi forecast results, the equation shown on page 12, computing the TotalLocalInflows, was rearranged to solve for Otowi:

ForecastAtOtowi = (Total Local Inflow+(routed(ForecastAtElVado) + routed(ForecastAtLobatos) + routed(ForecastAtRedRiver) + routed(ForecastAtRioPueblo) + routed(ForecastAtEmbudoCreek)) X adjustment factor)/adjustment factor

The forecasted results for each forecasted point and local inflows were substituted into this equation to solve for the forecasted flow at Otowi.

The results for the January through March forecasts are fairly self-explanatory. However, we should examine the April and May results a bit more closely. The April and May results show the impact of blending flows during the first three forecasted days to gradually blend big jumps between observed and forecasted flows. If blending were not used the results would be similar to the January through March forecasts. Considering that the NRCS forecasts are rounded to the nearest 100, 1,000, or 10,000 acre-feet, depending on the magnitude of the forecast, these results (even with blending) appear perfectly reasonable.

Table 3 – Forecast Model Test Results (1 Similar Year) – 1995 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1995	El Vado Reservoir Inflow	250	250	0
	Red River blw Fish Hatchery	44	44	0
	Rio Pueblo de Taos blw Los Cordovas	45	45	0
	Rio Blanco at Blanco Diversion	60	60	0
	Navajo River at Oso Diversion	75	75	0
	Otowi	800	799.97	0
	Jemez River nr Jemez	50	50	0
	Santa Fe River nr Santa Fe	3.0	3.0	0
February 1, 1995	El Vado Reservoir Inflow	250	250	0
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	57	57	0
	Rio Blanco at Blanco Diversion	60	60	0
	Navajo River at Oso Diversion	75	75	0
	Otowi	820	819.96	0
	Jemez River nr Jemez	65	65	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
March 1, 1995	El Vado Reservoir Inflow	279	279	0
	Red River blw Fish Hatchery	54	54	0
	Rio Pueblo de Taos blw Los Cordovas	65	65	0
	Rio Blanco at Blanco Diversion	64	64	0
	Navajo River at Oso Diversion	81	81	0
	Otowi	960	957.5	-0.26
	Jemez River nr Jemez	66	65.90	-0.15
	Santa Fe River nr Santa Fe	6.5	6.5	0
April 1, 1995	El Vado Reservoir Inflow	380.0	376.80	-0.84
	Red River blw Fish Hatchery	44.0	43.93	-0.16
	Rio Pueblo de Taos blw Los Cordovas	21.0	21.08	0.38
	Rio Blanco at Blanco Diversion	72.0	72.0	0
	Navajo River at Oso Diversion	92.0	92.0	0
	Otowi	1100.0	1090.4	-0.87
	Jemez River nr Jemez	55.0	55.0	0
	Santa Fe River nr Santa Fe	4.4	4.4	0
May 1, 1995	El Vado Reservoir Inflow	400	398.14	-0.46
	Red River blw Fish Hatchery	44	43.81	-0.43
	Rio Pueblo de Taos blw Los Cordovas	21	21.18	0.86
	Rio Blanco at Blanco Diversion	80	80.0	0
	Navajo River at Oso Diversion	100	100.0	0
	Otowi	1250	1247.66	-0.19
	Jemez River nr Jemez	70	69.04	-1.37
	Santa Fe River nr Santa Fe	5.5	5.49	-0.18

Table 3A – Forecast Model Test Results (2 Similar Years) – 1995 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1995	El Vado Reservoir Inflow	250	250	0
	Red River blw Fish Hatchery	44	44	0
	Rio Pueblo de Taos blw Los Cordovas	45	45	0
	Rio Blanco at Blanco Diversion	60	60	0
	Navajo River at Oso Diversion	75	75	0
	Otowi	800	799.97	0
	Jemez River nr Jemez	50	50	0
	Santa Fe River nr Santa Fe	3.0	3.0	0
February 1, 1995	El Vado Reservoir Inflow	250	250	0
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	57	57	0
	Rio Blanco at Blanco Diversion	60	60	0
	Navajo River at Oso Diversion	75	75	0
	Otowi	820	819.96	0
	Jemez River nr Jemez	65	65	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
March 1, 1995	El Vado Reservoir Inflow	279	279	0
	Red River blw Fish Hatchery	54	54	0
	Rio Pueblo de Taos blw Los Cordovas	65	65	0
	Rio Blanco at Blanco Diversion	64	64	0
	Navajo River at Oso Diversion	81	81	0
	Otowi	960	958.91	-0.11
	Jemez River nr Jemez	66	66	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
April 1, 1995	El Vado Reservoir Inflow	380.0	378.04	-0.52
	Red River blw Fish Hatchery	44.0	43.88	-0.27
	Rio Pueblo de Taos blw Los Cordovas	21.0	21.0	0
	Rio Blanco at Blanco Diversion	72.0	71.63	-0.51
	Navajo River at Oso Diversion	92.0	91.65	-0.38
	Otowi	1100.0	1093.27	-0.61
	Jemez River nr Jemez	55.0	55.0	0
	Santa Fe River nr Santa Fe	4.4	4.4	0
May 1, 1995	El Vado Reservoir Inflow	400	399.09	-0.23
	Red River blw Fish Hatchery	44	43.78	-0.50
	Rio Pueblo de Taos blw Los Cordovas	21	21.16	0.76
	Rio Blanco at Blanco Diversion	80	80.0	0
	Navajo River at Oso Diversion	100	100.0	0
	Otowi	1250	1243.65	-0.51
	Jemez River nr Jemez	70	69.27	-1.04
	Santa Fe River nr Santa Fe	5.5	5.48	-0.36

Table 3B – Forecast Model Test Results (5 Similar Years) – 1995 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1995	El Vado Reservoir Inflow	250	250	0
	Red River blw Fish Hatchery	44	44	0
	Rio Pueblo de Taos blw Los Cordovas	45	45	0
	Rio Blanco at Blanco Diversion	60	60	0
	Navajo River at Oso Diversion	75	75	0
	Otowi	800	799.96	0
	Jemez River nr Jemez	50	50	0
	Santa Fe River nr Santa Fe	3.0	3.0	0
February 1, 1995	El Vado Reservoir Inflow	250	250	0
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	57	57	0
	Rio Blanco at Blanco Diversion	60	60	0
	Navajo River at Oso Diversion	75	75	0
	Otowi	820	819.96	0
	Jemez River nr Jemez	65	65	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
March 1, 1995	El Vado Reservoir Inflow	279	278.90	0
	Red River blw Fish Hatchery	54	54	0
	Rio Pueblo de Taos blw Los Cordovas	65	65	0
	Rio Blanco at Blanco Diversion	64	64	0
	Navajo River at Oso Diversion	81	81	0
	Otowi	960	959.11	-0.10
	Jemez River nr Jemez	66	66	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
April 1, 1995	El Vado Reservoir Inflow	380.0	379.19	-0.21
	Red River blw Fish Hatchery	44.0	44.0	0
	Rio Pueblo de Taos blw Los Cordovas	21.0	21.10	-0.48
	Rio Blanco at Blanco Diversion	72.0	71.84	-0.22
	Navajo River at Oso Diversion	92.0	91.83	-0.18
	Otowi	1100.0	1096.06	-0.36
	Jemez River nr Jemez	55.0	55.0	0
	Santa Fe River nr Santa Fe	4.4	4.42	0.45
May 1, 1995	El Vado Reservoir Inflow	400	399.01	-0.25
	Red River blw Fish Hatchery	44	43.81	-0.43
	Rio Pueblo de Taos blw Los Cordovas	21	21.20	0.95
	Rio Blanco at Blanco Diversion	80	79.69	-0.39
	Navajo River at Oso Diversion	100	100.0	0
	Otowi	1250	1242.67	-0.59
	Jemez River nr Jemez	70	69.24	-1.10
	Santa Fe River nr Santa Fe	5.5	5.45	-0.91

Table 4 – Forecast Model Test Results – 1996 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1996	El Vado Reservoir Inflow	85.0	85.0	0
	Red River blw Fish Hatchery	15.0	15.0	0
	Rio Pueblo de Taos blw Los Cordovas	6.0	6.0	0
	Rio Blanco at Blanco Diversion	25.0	25.0	0
	Navajo River at Oso Diversion	30.0	30.0	0
	Otowi	245.0	244.99	0
	Jemez River nr Jemez	17.0	17.0	0
	Santa Fe River nr Santa Fe	2.5	2.5	0
February 1, 1996	El Vado Reservoir Inflow	100.0	100.0	0
	Red River blw Fish Hatchery	20.0	20.0	0
	Rio Pueblo de Taos blw Los Cordovas	19.0	19.0	0
	Rio Blanco at Blanco Diversion	30.0	30.0	0
	Navajo River at Oso Diversion	35.0	35.0	0
	Otowi	270.0	269.99	0
	Jemez River nr Jemez	18.0	18.0	0
	Santa Fe River nr Santa Fe	2.5	2.5	0
March 1, 1996	El Vado Reservoir Inflow	100.0	100.14	0.14
	Red River blw Fish Hatchery	18.0	18.0	0
	Rio Pueblo de Taos blw Los Cordovas	9.0	9.0	0
	Rio Blanco at Blanco Diversion	30.0	30.0	0
	Navajo River at Oso Diversion	35.0	35.0	0
	Otowi	270.0	270.37	0.14
	Jemez River nr Jemez	14.0	14.0	0
	Santa Fe River nr Santa Fe	1.5	1.5	0
April 1, 1996	El Vado Reservoir Inflow	91.0	91.17	0.19
	Red River blw Fish Hatchery	14.0	14.04	0.29
	Rio Pueblo de Taos blw Los Cordovas	6.8	6.83	0.44
	Rio Blanco at Blanco Diversion	25.0	25.0	0
	Navajo River at Oso Diversion	30.0	30.0	0
	Otowi	230.0	230.45	0.20
	Jemez River nr Jemez	10.0	10.0	0
	Santa Fe River nr Santa Fe	1.2	1.21	0.83
May 1, 1996	El Vado Reservoir Inflow	65.0	66.06	1.63
	Red River blw Fish Hatchery	13.0	13.05	0.38
	Rio Pueblo de Taos blw Los Cordovas	6.8	6.83	0.44
	Rio Blanco at Blanco Diversion	25.0	25.27	1.08
	Navajo River at Oso Diversion	30.0	30.21	0.70
	Otowi	200.0	202.27	1.14
	Jemez River nr Jemez	9.0	8.91	-1.0
	Santa Fe River nr Santa Fe	1.0	1.02	2.00

Table 4A – Forecast Model Test Results (2 Similar Years) – 1996 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1996	El Vado Reservoir Inflow	85.0	85.0	0
	Red River blw Fish Hatchery	15.0	15.0	0
	Rio Pueblo de Taos blw Los Cordovas	6.0	6.0	0
	Rio Blanco at Blanco Diversion	25.0	25.0	0
	Navajo River at Oso Diversion	30.0	30.0	0
	Otowi	245.0	244.99	0
	Jemez River nr Jemez	17.0	17.0	0
	Santa Fe River nr Santa Fe	2.5	2.5	0
February 1, 1996	El Vado Reservoir Inflow	100.0	100.0	0
	Red River blw Fish Hatchery	20.0	20.0	0
	Rio Pueblo de Taos blw Los Cordovas	19.0	19.0	0
	Rio Blanco at Blanco Diversion	30.0	30.0	0
	Navajo River at Oso Diversion	35.0	35.0	0
	Otowi	270.0	269.99	0
	Jemez River nr Jemez	18.0	18.0	0
	Santa Fe River nr Santa Fe	2.5	2.5	0
March 1, 1996	El Vado Reservoir Inflow	100.0	99.88	-0.12
	Red River blw Fish Hatchery	18.0	18.0	0
	Rio Pueblo de Taos blw Los Cordovas	9.0	9.0	0
	Rio Blanco at Blanco Diversion	30.0	30.0	0
	Navajo River at Oso Diversion	35.0	35.0	0
	Otowi	270.0	270.56	0.21
	Jemez River nr Jemez	14.0	14.0	0
	Santa Fe River nr Santa Fe	1.5	1.5	0
April 1, 1996	El Vado Reservoir Inflow	91.0	90.75	-0.27
	Red River blw Fish Hatchery	14.0	14.03	0.21
	Rio Pueblo de Taos blw Los Cordovas	6.8	6.8	0
	Rio Blanco at Blanco Diversion	25.0	25.0	0
	Navajo River at Oso Diversion	30.0	30.0	0
	Otowi	230.0	229.80	0
	Jemez River nr Jemez	10.0	10.0	0
	Santa Fe River nr Santa Fe	1.2	1.21	0.83
May 1, 1996	El Vado Reservoir Inflow	65.0	66.18	1.82
	Red River blw Fish Hatchery	13.0	13.03	0.23
	Rio Pueblo de Taos blw Los Cordovas	6.8	6.8	0
	Rio Blanco at Blanco Diversion	25.0	25.25	1.0
	Navajo River at Oso Diversion	30.0	30.19	0.63
	Otowi	200.0	201.72	0.86
	Jemez River nr Jemez	9.0	8.87	-1.44
	Santa Fe River nr Santa Fe	1.0	1.02	2.00

Table 4B – Forecast Model Test Results (5 Similar Years) – 1996 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1996	El Vado Reservoir Inflow	85.0	85.0	0
	Red River blw Fish Hatchery	15.0	15.0	0
	Rio Pueblo de Taos blw Los Cordovas	6.0	6.0	0
	Rio Blanco at Blanco Diversion	25.0	25.0	0
	Navajo River at Oso Diversion	30.0	30.0	0
	Otowi	245.0	244.99	0
	Jemez River nr Jemez	17.0	17.0	0
	Santa Fe River nr Santa Fe	2.5	2.5	0
February 1, 1996	El Vado Reservoir Inflow	100.0	100.0	0
	Red River blw Fish Hatchery	20.0	20.0	0
	Rio Pueblo de Taos blw Los Cordovas	19.0	19.0	0
	Rio Blanco at Blanco Diversion	30.0	30.0	0
	Navajo River at Oso Diversion	35.0	35.0	0
	Otowi	270.0	269.99	0
	Jemez River nr Jemez	18.0	18.0	0
	Santa Fe River nr Santa Fe	2.5	2.5	0
March 1, 1996	El Vado Reservoir Inflow	100.0	99.88	-0.12
	Red River blw Fish Hatchery	18.0	18.0	0
	Rio Pueblo de Taos blw Los Cordovas	9.0	9.0	0
	Rio Blanco at Blanco Diversion	30.0	30.0	0
	Navajo River at Oso Diversion	35.0	35.0	0
	Otowi	270.0	270.56	0.21
	Jemez River nr Jemez	14.0	14.0	0
	Santa Fe River nr Santa Fe	1.5	1.5	0
April 1, 1996	El Vado Reservoir Inflow	91.0	91.0	0
	Red River blw Fish Hatchery	14.0	14.05	0.36
	Rio Pueblo de Taos blw Los Cordovas	6.8	6.85	0.74
	Rio Blanco at Blanco Diversion	25.0	25.10	0.40
	Navajo River at Oso Diversion	30.0	30.08	0.27
	Otowi	230.0	230.47	0.20
	Jemez River nr Jemez	10.0	10.0	0
	Santa Fe River nr Santa Fe	1.2	1.22	1.7
May 1, 1996	El Vado Reservoir Inflow	65.0	65.74	1.13
	Red River blw Fish Hatchery	13.0	13.03	0.23
	Rio Pueblo de Taos blw Los Cordovas	6.8	6.82	0.29
	Rio Blanco at Blanco Diversion	25.0	25.21	0.84
	Navajo River at Oso Diversion	30.0	30.21	0.70
	Otowi	200.0	201.14	0.57
	Jemez River nr Jemez	9.0	8.89	-1.22
	Santa Fe River nr Santa Fe	1.0	1.02	2.0

Table 5 – Forecast Model Test Results – 1997 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1997	El Vado Reservoir Inflow	280	280	0
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	56	56	0
	Rio Blanco at Blanco Diversion	65	65	0
	Navajo River at Oso Diversion	80	80	0
	Otowi	900	899.96	0
	Jemez River nr Jemez	50	50	0
	Santa Fe River nr Santa Fe	5.4	5.4	0
February 1, 1997	El Vado Reservoir Inflow	350	350	0
	Red River blw Fish Hatchery	53	53	0
	Rio Pueblo de Taos blw Los Cordovas	30	30	0
	Rio Blanco at Blanco Diversion	75	75	0
	Navajo River at Oso Diversion	95	95	0
	Otowi	1175	1174.95	0
	Jemez River nr Jemez	60	60	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
March 1, 1997	El Vado Reservoir Inflow	340	340.17	0.05
	Red River blw Fish Hatchery	50	49.91	-0.18
	Rio Pueblo de Taos blw Los Cordovas	26	26	0
	Rio Blanco at Blanco Diversion	80	80	0
	Navajo River at Oso Diversion	95	95	0
	Otowi	1125	1123.01	-0.18
	Jemez River nr Jemez	60	60	0
	Santa Fe River nr Santa Fe	5.5	5.5	0
April 1, 1997	El Vado Reservoir Inflow	250.0	251.08	0.72
	Red River blw Fish Hatchery	33.0	33.0	0
	Rio Pueblo de Taos blw Los Cordovas	32.0	32.0	0
	Rio Blanco at Blanco Diversion	70.0	69.42	-0.83
	Navajo River at Oso Diversion	85.0	85.0	0
	Otowi	850.0	848.72	-0.15
	Jemez River nr Jemez	37.0	37.39	1.05
	Santa Fe River nr Santa Fe	4.5	4.47	-0.67
May 1, 1997	El Vado Reservoir Inflow	260.0	260.02	0
	Red River blw Fish Hatchery	37.0	37.0	0
	Rio Pueblo de Taos blw Los Cordovas	40.0	40.08	0.20
	Rio Blanco at Blanco Diversion	25.0	25.12	0.48
	Navajo River at Oso Diversion	30.0	30.22	0.73
	Otowi	955.0	954.66	-0.04
	Jemez River nr Jemez	43.0	43.0	0
	Santa Fe River nr Santa Fe	4.5	4.5	0

Table 5A – Forecast Model Test Results (2 Similar Years) – 1997 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1997	El Vado Reservoir Inflow	280	280	0
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	56	56	0
	Rio Blanco at Blanco Diversion	65	65	0
	Navajo River at Oso Diversion	80	80	0
	Otowi	900	899.96	0
	Jemez River nr Jemez	50	50	0
	Santa Fe River nr Santa Fe	5.4	5.4	0
February 1, 1997	El Vado Reservoir Inflow	350	350	0
	Red River blw Fish Hatchery	53	53	0
	Rio Pueblo de Taos blw Los Cordovas	30	30	0
	Rio Blanco at Blanco Diversion	75	75	0
	Navajo River at Oso Diversion	95	95	0
	Otowi	1175	1174.95	0
	Jemez River nr Jemez	60	60	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
March 1, 1997	El Vado Reservoir Inflow	340	340.24	0.07
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	26	26	0
	Rio Blanco at Blanco Diversion	80	80	0
	Navajo River at Oso Diversion	95	95	0
	Otowi	1125	1123.28	-0.15
	Jemez River nr Jemez	60	60	0
	Santa Fe River nr Santa Fe	5.5	5.5	0
April 1, 1997	El Vado Reservoir Inflow	250.0	251.42	0.57
	Red River blw Fish Hatchery	33.0	33.0	0
	Rio Pueblo de Taos blw Los Cordovas	32.0	32.0	0
	Rio Blanco at Blanco Diversion	70.0	69.74	-0.37
	Navajo River at Oso Diversion	85.0	85.0	0
	Otowi	850.0	850.61	0.07
	Jemez River nr Jemez	37.0	37.27	0.73
	Santa Fe River nr Santa Fe	4.5	4.5	0
May 1, 1997	El Vado Reservoir Inflow	260.0	256.06	-1.51
	Red River blw Fish Hatchery	37.0	37.0	0
	Rio Pueblo de Taos blw Los Cordovas	40.0	40.0	0
	Rio Blanco at Blanco Diversion	25.0	25.10	0.40
	Navajo River at Oso Diversion	30.0	30.20	0.67
	Otowi	955.0	946.35	-0.91
	Jemez River nr Jemez	43.0	43.0	0
	Santa Fe River nr Santa Fe	4.5	4.49	-0.22

Table 5B – Forecast Model Test Results (5 Similar Years) – 1997 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1997	El Vado Reservoir Inflow	280	280	0
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	56	56	0
	Rio Blanco at Blanco Diversion	65	65	0
	Navajo River at Oso Diversion	80	80	0
	Otowi	900	899.96	0
	Jemez River nr Jemez	50	50	0
	Santa Fe River nr Santa Fe	5.4	5.4	0
February 1, 1997	El Vado Reservoir Inflow	350	350	0
	Red River blw Fish Hatchery	53	53	0
	Rio Pueblo de Taos blw Los Cordovas	30	30	0
	Rio Blanco at Blanco Diversion	75	75	0
	Navajo River at Oso Diversion	95	95	0
	Otowi	1175	1174.95	0
	Jemez River nr Jemez	60	60	0
	Santa Fe River nr Santa Fe	6.5	6.5	0
March 1, 1997	El Vado Reservoir Inflow	340	340.24	0.07
	Red River blw Fish Hatchery	50	50	0
	Rio Pueblo de Taos blw Los Cordovas	26	26	0
	Rio Blanco at Blanco Diversion	80	80	0
	Navajo River at Oso Diversion	95	95	0
	Otowi	1125	1123.34	-0.15
	Jemez River nr Jemez	60	60	0
	Santa Fe River nr Santa Fe	5.5	5.5	0
April 1, 1997	El Vado Reservoir Inflow	250.0	251.48	0.59
	Red River blw Fish Hatchery	33.0	33.0	0
	Rio Pueblo de Taos blw Los Cordovas	32.0	32.0	0
	Rio Blanco at Blanco Diversion	70.0	70.0	0
	Navajo River at Oso Diversion	85.0	85.0	0
	Otowi	850.0	850.85	0.10
	Jemez River nr Jemez	37.0	37.27	0.73
	Santa Fe River nr Santa Fe	4.5	4.5	0
May 1, 1997	El Vado Reservoir Inflow	260.0	257.22	-1.07
	Red River blw Fish Hatchery	37.0	36.83	-0.46
	Rio Pueblo de Taos blw Los Cordovas	40.0	39.66	-0.85
	Rio Blanco at Blanco Diversion	25.0	25.0	0
	Navajo River at Oso Diversion	30.0	30.22	0.73
	Otowi	955.0	945.0	-1.05
	Jemez River nr Jemez	43.0	43.0	0
	Santa Fe River nr Santa Fe	4.5	4.46	-0.89

Table 6 – Forecast Model Test Results (1 Similar Year) – 1998 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1998	El Vado Reservoir Inflow	240	240	0
	Red River blw Fish Hatchery	39	39	0
	Rio Pueblo de Taos blw Los Cordovas	20	20	0
	Rio Blanco at Blanco Diversion	54	54	0
	Navajo River at Oso Diversion	65	65	0
	Otowi	780	779.97	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	5.5	5.5	0
February 1, 1998	El Vado Reservoir Inflow	210	210	0
	Red River blw Fish Hatchery	33	33	0
	Rio Pueblo de Taos blw Los Cordovas	38	38	0
	Rio Blanco at Blanco Diversion	50	50	0
	Navajo River at Oso Diversion	60	60	0
	Otowi	700	799.97	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	4.3	4.3	0
March 1, 1998	El Vado Reservoir Inflow	180	179.96	-0.02
	Red River blw Fish Hatchery	33	33	0
	Rio Pueblo de Taos blw Los Cordovas	17.5	17.5	0
	Rio Blanco at Blanco Diversion	45	45	0
	Navajo River at Oso Diversion	53	53	0
	Otowi	560	560	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	4.3	4.3	0
April 1, 1998	El Vado Reservoir Inflow	185.0	185.42	0.23
	Red River blw Fish Hatchery	35.0	35.0	0
	Rio Pueblo de Taos blw Los Cordovas	18.0	18.0	0
	Rio Blanco at Blanco Diversion	45.0	45.0	0
	Navajo River at Oso Diversion	55.0	55.0	0
	Otowi	580.0	580.37	0.06
	Jemez River nr Jemez	40.0	39.63	-0.93
	Santa Fe River nr Santa Fe	5.0	5.0	0
May 1, 1998	El Vado Reservoir Inflow	200.0	196.53	-1.74
	Red River blw Fish Hatchery	36.0	35.70	-0.83
	Rio Pueblo de Taos blw Los Cordovas	38.0	37.14	-2.26
	Rio Blanco at Blanco Diversion	50.0	50.20	0.40
	Navajo River at Oso Diversion	60.0	60.22	0.37
	Otowi	680.0	673.45	-0.96
	Jemez River nr Jemez	40.0	40.0	0
	Santa Fe River nr Santa Fe	6.0	5.87	-2.17

Table 6A – Forecast Model Test Results (2 Similar Years) – 1998 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1998	El Vado Reservoir Inflow	240	240	0
	Red River blw Fish Hatchery	39	39	0
	Rio Pueblo de Taos blw Los Cordovas	20	20	0
	Rio Blanco at Blanco Diversion	54	54	0
	Navajo River at Oso Diversion	65	65	0
	Otowi	780	779.97	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	5.5	5.5	0
February 1, 1998	El Vado Reservoir Inflow	210	210	0
	Red River blw Fish Hatchery	33	33	0
	Rio Pueblo de Taos blw Los Cordovas	38	38	0
	Rio Blanco at Blanco Diversion	50	50	0
	Navajo River at Oso Diversion	60	60	0
	Otowi	700	699.97	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	4.3	4.3	0
March 1, 1998	El Vado Reservoir Inflow	180	179.86	-0.08
	Red River blw Fish Hatchery	33	33	0
	Rio Pueblo de Taos blw Los Cordovas	17.5	17.5	0
	Rio Blanco at Blanco Diversion	45	45	0
	Navajo River at Oso Diversion	53	53	0
	Otowi	560	559.22	-0.14
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	4.3	4.3	0
April 1, 1998	El Vado Reservoir Inflow	185.0	184.69	-0.17
	Red River blw Fish Hatchery	35.0	34.91	-0.26
	Rio Pueblo de Taos blw Los Cordovas	18.0	18.0	0
	Rio Blanco at Blanco Diversion	45.0	45.0	0
	Navajo River at Oso Diversion	55.0	55.0	0
	Otowi	580.0	578.61	-0.24
	Jemez River nr Jemez	40.0	40.0	0
	Santa Fe River nr Santa Fe	5.0	5.0	0
May 1, 1998	El Vado Reservoir Inflow	200.0	195.32	-2.34
	Red River blw Fish Hatchery	36.0	35.87	-0.36
	Rio Pueblo de Taos blw Los Cordovas	38.0	37.62	-1.0
	Rio Blanco at Blanco Diversion	50.0	50.0	0
	Navajo River at Oso Diversion	60.0	60.0	0
	Otowi	680.0	670.49	-1.40
	Jemez River nr Jemez	40.0	40.0	0
	Santa Fe River nr Santa Fe	6.0	5.92	-1.33

Table 6B – Forecast Model Test Results (5 Similar Years) – 1998 NRCS Forecasts

NRCS FORECAST	FORECAST POINT	NRCS FORECAST (KAF)	MODEL VOLUME (KAF)	PERCENT DIFFERENCE
January 1, 1998	El Vado Reservoir Inflow	240	240	0
	Red River blw Fish Hatchery	39	39	0
	Rio Pueblo de Taos blw Los Cordovas	20	20	0
	Rio Blanco at Blanco Diversion	54	54	0
	Navajo River at Oso Diversion	65	65	0
	Otowi	780	779.97	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	5.5	5.5	0
February 1, 1998	El Vado Reservoir Inflow	210	210	0
	Red River blw Fish Hatchery	33	33	0
	Rio Pueblo de Taos blw Los Cordovas	38	38	0
	Rio Blanco at Blanco Diversion	50	50	0
	Navajo River at Oso Diversion	60	60	0
	Otowi	700	669.97	0
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	4.3	4.3	0
March 1, 1998	El Vado Reservoir Inflow	180	179.95	-0.03
	Red River blw Fish Hatchery	33	33	0
	Rio Pueblo de Taos blw Los Cordovas	17.5	17.5	0
	Rio Blanco at Blanco Diversion	45	45	0
	Navajo River at Oso Diversion	53	53	0
	Otowi	560	559.62	-0.07
	Jemez River nr Jemez	51	51	0
	Santa Fe River nr Santa Fe	4.3	4.3	0
April 1, 1998	El Vado Reservoir Inflow	185.0	185.05	0.03
	Red River blw Fish Hatchery	35.0	35.0	0
	Rio Pueblo de Taos blw Los Cordovas	18.0	18.04	0.22
	Rio Blanco at Blanco Diversion	45.0	45.0	0
	Navajo River at Oso Diversion	55.0	55.0	0
	Otowi	580.0	580.07	0.01
	Jemez River nr Jemez	40.0	40.0	0
	Santa Fe River nr Santa Fe	5.0	5.01	0.20
May 1, 1998	El Vado Reservoir Inflow	200.0	199.77	-0.12
	Red River blw Fish Hatchery	36.0	35.87	-0.36
	Rio Pueblo de Taos blw Los Cordovas	38.0	37.58	-1.11
	Rio Blanco at Blanco Diversion	50.0	50.0	0
	Navajo River at Oso Diversion	60.0	60.0	0
	Otowi	680.0	675.29	-0.69
	Jemez River nr Jemez	40.0	40.0	0
	Santa Fe River nr Santa Fe	6.0	5.95	-0.83

5.0 Conclusion

The Forecast model adequately maintains the NRCS forecast volume for each forecast point when disaggregating the runoff period volume to generate daily flow values for use in other models. This method of forecasting flows may eventually be replaced by other methods such as the MMS or CWMS, but still may be needed in the future for forecasting other parameters though, such as diversions, wastewater returns, precipitation, etc.

The Forecast model does give the user a fair amount of flexibility in generating forecasted values, but it also requires the user to verify that the model produced the desired results. Just as with any computer model, it is a tool to be used by experienced individuals, particularly in the case of water resources uses.